# 1. SURVEY BACKGROUND AND METHODOLOGY

## 1.1. Introduction

The National Survey of Academic Research Instruments and Instrumentation Needs (instrumentation survey) is a congressionally mandated program that collects data concerning scientific research instruments[1] and the academic units (departments and facilities)[2] in which they are located for a broad spectrum of science and engineering (S&E) fields. The instrumentation survey is conducted by the National Science Foundation (NSF), and is co-sponsored by the National Institutes of Health (NIH).

This report describes recent trends in academic research instrumentation and instrumentation needs specifically in the biological sciences, and in seven major subfields of the biological sciences: biochemistry, cell biology/genetics, microbiology, pathology, pharmacology, physiology/biophysics, and other biological sciences.

This report provides an analysis of data collected from two distinct populations of institutions. The first population consists of the 318 institutions that performed a minimum of $3 million in research and development in 1991. This population has been the traditional focus of the instrumentation survey since its inception in 1983. The second population consists of 44 historically black colleges and universities (HBCUs) that reported research and development (R&D) expenditures in the biological sciences in 1991. This population was added to the instrumentation survey for the first time in 1994.

A companion report, *Academic Research Instruments: Expenditures 1993 and Needs 1994*,[3] analyzes overall instrumentation issues and trends in all the fields covered by the survey: agriculture, biology, computer science, environmental science, physics/astronomy/chemistry, and engineering.

## 1.2. Background

During the late 1970s, reports came before Congress suggesting that the capability of research instrumentation available to scientists and engineers at leading research universities was often inadequate in meeting the needs of cutting-edge research. It was feared that this condition might

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[1] A broad approach was used to determine which instruments should be included in this survey. Therefore, an instrument is said to be used for research even if the predominant use is for instruction.

[2] An academic department is a degree-granting unit; a facility is a non-degree-granting unit. Units include both departments and facilities.

[3] Copies of this report may be obtained by writing Carolyn Arena, Division of Science Resources Studies, National Science Foundation, Room 965, 4201 Wilson Boulevard, Arlington, VA 22230, or by sending an e-mail to carena@nsf.gov. Please include your name and address, and the publication title.

seriously weaken the quality of the Nation's academic research capabilities. For informed policy decisions, however, more information was required regarding the amount, cost, condition, and needs for academic research instruments. Therefore, Congress directed NSF to " . . . develop indices, correlates, or other suitable measures or indicators of the status of scientific instrumentation in the United States and of the current and projected needs for scientific and technological instrumentation." (Public Law 96-44, Section 7)

To fulfill this congressional directive, NSF, in conjunction with NIH, conducted an instrumentation survey of four main aspects of academic research instrumentation:

1. expenditures made by departments and facilities for the purchase of research instruments and the sources of funds for those purchases;

2. maintenance, repair, and operating costs connected with the stock of research instruments;

3. status, adequacy, and capability of current research instruments; and

4. needs for upgraded or additional research instrumentation.

## 1.3. Instrumentation Survey Methodology

This is the fourth cycle of the instrumentation survey. The first cycle of the survey was conducted in 1983–84. This baseline survey had a panel of 67 institutions: 43 colleges and universities and 24 medical colleges.

For the second cycle of the survey, conducted in 1986–87, the sample of colleges and universities was expanded to 55 schools. This sample produced a panel representing 79 institutions. This same panel was used in both the third cycle of the survey, conducted in 1989–90, and the fourth cycle of the survey. This same panel was selected from the population of all institutions that performed a minimum of $3 million in R&D annually. In this (fourth) cycle, it represented 318 institutions; in the third cycle, it represented 287 institutions; in the second cycle it represented 174 institutions; and in the first it represented 155.

In each cycle of the survey, two types of data were collected from two different sets of respondents:

- The heads of academic departments and research facilities completed a *Department/Facility Questionnaire* in which they provided data for their entire units regarding expenditures for purchasing research instruments, the sources of these funds, their provisions for maintaining and repairing the instruments, and an evaluation of all their research instruments in terms of adequacy, capabilities, and needs. These data are presented in Chapter 2 of this report.

- Principal investigators completed an *Instrument Data Sheet* in which they provided data about individual pieces of research instruments (e.g., their adequacy for research,

pattern of usage, and technical capabilities). These data are presented in Chapter 3 of this report.

## 1.4. Current Panel Survey Methodology (Cycle IV)

In the fourth cycle of the instrumentation survey, data were collected from departments and facilities having at least one research instrument with a minimum purchase price of $20,000. These academic departments and facilities were located at the 79 colleges, universities, and medical schools selected from the population of institutions that perform a minimum of $3 million annually in R&D. This population consisted of the 318 institutions that accounted for more than 90 percent of the expenditures for academic R&D in science and engineering in the United States.

The panel of 79 institutions was divided into two samples:

- The first sample—55 colleges and universities (excluding their medical colleges, if any)—represented the universe of 214 institutions that had R&D expenditures of more than $3 million each in FY 1991. The probability of selection for institutions in this sample was proportionate to the total expenditures for R&D in FY 1991 for those S&E fields included in the instrumentation survey (agriculture, biology, computer science, environmental science, physics/astronomy/chemistry, and engineering).

- The second sample—24 medical schools (including medical components of colleges and universities)—represented the universe of 104 medical schools that received at least $3 million in extramural awards for research from NIH in FY 1991. The probability of selection for elements in this second sample was approximately proportionate to the total amount of dollars given to medical institutions for extramural awards by NIH in FY 1991.

The institutions in both of these samples are listed in Appendix B.

Sampled institutions contained a total of 1,541 S&E departments and facilities with at least one research instrument with a minimum purchase price of $20,000. Of these, 467 were biological science departments and facilities in the subfields of biochemistry, cell biology/genetics, microbiology, pathology, pharmacology, physiology/biophysics, and other biological sciences.[4]

A sample of 234 in-scope biology departments and facilities was selected. Departments and facilities were considered in-scope if they had at least one research instrument with a minimum purchase cost of $20,000. Data also were collected for a sample of 1,231 in-scope research instruments that were located in these academic units. An instrument was considered to be in-

[4] Other biological sciences include anatomy, biometry, botany, ecology, epidemiology, nutrition, zoology, and interdisciplinary biomedical research units.

scope if it was serviceable and in use during the reporting period of the survey, was movable,[5] had a minimum purchase price of $20,000, was used at least in part to conduct research in the biological sciences, and was located in a biological science unit that was in-scope for the instrumentation survey.[6] The sampling plan followed for selecting the biology departments and facilities is available in a separate methodology report, *National Survey of Academic Research Instruments and Instrumentation Needs, Methodology Report: 1993.*[7]

The findings from the instrumentation survey were presented as national estimates. The estimates based on the department and facility data were statistically weighted to represent all research departments and facilities in the agriculture, biology, environmental science, physics, and computer sciences, and in engineering. The final weights for these estimates were the product of the institution sampling weight (for each stratum), and the non-response adjustment factors for the institution and department or facility. The estimates based upon the instrument data were calculated using data statistically weighted to represent all research instruments in agriculture, biology, chemistry, environmental science, physics/astronomy, computer sciences, and in engineering. The final weights for these estimates were the product of the institutional sampling weight (for each stratum) and the non-response adjustment factors for the research instruments.

These results were generalized to the universe of 318 institutions from which the panel of 79 institutions was drawn. In addition, some of the findings were compared with those from the previous three cycles. Data for the estimated expenditures for the purchase, maintenance/repair, and operation of scientific research instrumentation were presented in current dollars. They have not been adjusted for inflation.

### 1.4.1. Panel Response Rates

Data were received from 54 of the 55 institutions in the sample of colleges and universities and from all 24 institutions in the sample of medical schools. Of the 234 biological science departments and facilities in the sample, 198 responded to the survey (85 percent). The response rate for the *Department/Facility Questionnaire* items ranged from 86 to 100 percent. Finally, a

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[5] Large, permanently placed research instruments such as fume hoods, laboratory benches, and cold rooms are not within the scope of the instrumentation survey. These instruments, along with the infrastructure needed to support these instruments, are included in the *Survey of Scientific Research Facilities at Universities and Colleges*.

[6] Research instruments located in clinical science units and non-medical health professional schools, including veterinary schools, were not within the scope of this survey. Also excluded from this survey were research instruments located at federally funded research and development centers (FFRDCs), even though these instruments might have been physically located on the campus of a participating institution. Research instruments that were physically located in a laboratory or other facility located on the university's campus, but not administered by the university, also were excluded.

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sample of 1,231 in-scope instruments was selected. Of these, data for 977 were received (a response rate of 79 percent). The item response rates for the *Instrument Data Sheet* ranged from 83 to 100 percent.

### 1.4.2. Changes in Data Collection Procedures[8]

The data collection procedures used in Cycle IV's 1994 survey differ from those used in earlier cycles of the instrumentation survey in the minimum instrument purchase price criterion used.

For instance, to be eligible for inclusion in the three previous cycles of the survey, a department or facility must have had at least one research instrument with a purchase price greater than or equal to $10,000. Similarly, only those research instruments with a purchase price greater than or equal to $10,000 were eligible for inclusion in the instrument sample.

In Cycle IV, the $10,000 minimum purchase price criterion was increased to $20,000. Trend data for previous cycles of the survey were adjusted to reflect this change. Data from the 1982–83, 1985–86, and 1988–89 surveys were standardized using the same minimum purchase price criterion of $20,000 in constant 1993 dollars, according to the gross domestic product (GDP) implicit price deflator.[9] Beginning in Cycle III, data were collected for instruments with a purchase price greater than or equal to $1 million.

Many of these instruments consisted of a single system of interrelated equipment[10] that could not meaningfully be disaggregated for data collection purposes (e.g., research vessels, nuclear reactors, and central computer facilities/centers). These single systems are thus referred to as supersystems. Overall, for all fields of S&E, there were 121 integrated supersystems in Cycle III, and only 2 of these were located in the sampled biological science departments and facilities. In Cycle IV, there were no supersystems located in biological science units. Therefore, the effect of supersystems on trend estimates presented in this report is minimal, and data for supersystems are included in the analyses of both academic units and research instruments.

### 1.4.3. Survey Data Reference Periods

Data collected from departments and facilities in the panel of institutions have two separate reference periods. Information about current equipment needs and priorities in the biological sciences was obtained with reference to the year the survey data were collected (i.e., 1984, 1987,

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[8] In an effort to reduce respondent burden in 1992 only the *Department/Facility Questionnaire* was used to gather instrument expenditures and needs for the total unit. Due to several methodological problems with this approach, the 1992 survey results are not included in this report's trend data.

[9] The procedures by which this was done are explained in the separate methodology report, *National Survey of Academic Research Instruments and Instrumentation Needs, Methodology Report: 1993*.

[10] The terms 'equipment' and 'instruments' are used interchangeably in this report.

1990, and 1994). Information about equipment dollar amounts and expenditures refers to the year preceding the survey's data collection year (i.e., 1983, 1986, 1989, and 1993). Data collected for research instruments also refer to the year preceding the survey's data collection year.[11]

### 1.4.4. Sampling Errors

The national estimates for the population of 318 R&D institutions presented in this report are based on samples and are subject to variability due to sampling error. Most overall estimates (not broken down by field of science and engineering) for variables pertaining to the biological science departments and facilities have sampling errors (coefficients of variation) that range from 5 to 7 percent. This implies a 95-percent confidence interval of twice that magnitude; i.e., plus or minus 10 to 14 percent of the reported estimate. Estimates for the detail data (i.e., estimates by field of science) have sampling errors two to three times larger than those for all fields combined.[12]

Variables based upon data collected for the biological sciences research instruments have sampling errors (coefficients of variation) of approximately 2 percent. This implies a 95-percent confidence interval of twice that magnitude; i.e., plus or minus 4 percent of the reported estimate.

## 1.5. Historically Black Colleges and Universities Survey Methodology

In 1994–95, a population of HBCUs was surveyed to obtain the status of their research instrumentation in biological sciences. However, because most HBCUs are considerably smaller than the 79 research institutions that participate in the panel survey,[13] NSF/NIH asked that the procedures used to collect data for the instrumentation survey be carefully tested. Testing was done in two phases.

### 1.5.1. Phase 1, Testing

In Phase 1, site visits were made to the biological science units in nine HBCUs. The purpose of these visits was to pretest the instrumentation survey questionnaires and to determine the

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[11] The data collection in Cycles I-III was done as part of a two year process. The data for biology were collected in 1983, 1986, and 1989. Data for all fields of science were collected in 1993,the fourth cycle of the survey.

[12] For example, the estimated total annual expenditures for the purchase of academic scientific research instrumentation in the biological sciences were $283 million in 1993. Assuming a sampling error of 7 percent, one may be 95 percent confident that the true amount of expenditures for research instrumentation will be found within the interval of $243 million to $323 million.

[13] Although some of the HBCUs conducted more than $3 million in research and development, the minimum criterion for inclusion in the panel survey, only 56 of the HBCUs participated in the Survey of Scientific and Engineering Expenditures at Universities and Colleges in 1991 and reported any R&D expenditures in science and engineering. Only 44 of these reported any R&D expenditures in biology.

suitability of the data collection procedure. These visits were conducted from August 27–November 3, 1992. Details of these visits are presented in a separate methodology report, *National Survey of Academic Research Instruments and Instrumentation Needs, Methodology Report: 1993.*[14]

The principal finding of the site visits was that the questionnaires and data collection procedures used for the panel of 79 large research institutions could be used, with some modification, to conduct the survey of the HBCUs. The primary modification was to reduce the minimum equipment purchase price criterion from $20,000 to $10,000. This change was made to accommodate the relatively low density of biological research instruments found at the HBCUs: six of the nine institutions visited had less than five pieces of equipment with a purchase price greater than or equal to $20,000.

Finally, the criteria for selecting the HBCUs to be included in the instrumentation survey were reevaluated. Initially, it was planned to collect data from the 46 HBCUs that participate in the NSF/NIH Facilities Survey so that the results of the two surveys could be compared. However, 11 of these schools had no R&D expenditures in the biological sciences in 1991.[15] Therefore, the selection criterion was amended to include only the 44 HBCUs that reported R&D expenditures in the biological sciences in 1991.

### 1.5.2. Phase 2, Data Collection

In Phase 2 of the testing, data for the biological sciences (departments and instruments) were collected and analyzed from a population of 44 HBCUs.

#### 1.5.2.1. Test Methodology

The procedures used to collect data for biological research instruments from the population of HBCUs were the same as those used to collect data from the panel of 79 large research universities—with the exception that institutions, departments, and instruments were not sampled in the survey of HBCUs. The data collection period for the HBCUs was from May 1994, when letters were mailed to the institutions' presidents, to August 1995.

Each of the 44 HBCUs in the survey was asked to provide an inventory of the research instruments with a minimum purchase price of $10,000 in the biological science units. The inventory included the name of the research instrument, its location, date of purchase, and the

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[15] These 11 institutions were not included in the population for the instrumentation survey. They were replaced by nine institutions that reported R&D expenditures for the biological sciences in 1991 but were not included in the facilities survey.

name of the principal investigator. There were 57 biological science units surveyed at the HBCUs. All were asked to complete a department/facility questionnaire. Of these 57 units, 46 reported having at least one research instrument with a purchase price of $10,000 or more. The inventories for these 46 units provided data for a total of 381 instruments. All instruments were selected for analysis; sampling was not used. Of the 381 instrument questionnaires mailed to either the department chairpersons, facility directors, or principal investigators, 303 were completed and returned. Of the 303 questionnaires returned, 293 were in-scope. These 293 questionnaires were adjusted for the 78 non-respondents, and a total of 338 research instruments was used for analysis.

#### 1.5.2.2. Standard Errors

As noted above, data were collected from the population of 44 HBCUs that reported R&D expenditures in the biological sciences in 1991. Neither units nor instruments were sampled. The data for these units are extremely skewed. Many of the variables have a large number of observations with a value of zero and a small number of observations with very high value. For example, the total value of the biological research equipment that was purchased in 1993 (as reported by the unit-level respondents) was $4,921 thousand. The range for this value was from $1.45 million to zero dollars. Of the 55 departments that reported data for this variable, 9 reported zero dollars and 10 reported over $100 thousand. The data for the total cost of maintenance and repair, total cost of operations, and total aggregate purchase price were similarly distributed.

Consequently the standard errors (coefficients of variation) are also quite large, ranging from 147 percent to 247 percent. Because data were collected from a population of HBCUs, the standard errors are not required to interpret the statistical significance of the reported results. They should be used only as an indicator of the extreme variation that was found among the variables reported by the HBCUs.